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1.	Your reference	P3055-GB
2.	Patent application number *(The Patent Office will fill in this pa*	0229432.0 — 18 DEC 2002
		19DEC02 E771867-1 D02802
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Flux Solutions Limited P01/7700 0.00-0229432.0 St Michael's Business Centre Church Street Lyme Regis Dorset DT7 3DB
	Patents ADP number *(if you know it)*	
	If the applicant is a corporate body, give the country/state of its incorporation	85290/8001
4.	Title of the invention	Image Display System
5.	Name of your agent *(if you have one)*	K R Bryer & Co
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	7 Gay Street Bath BA1 2PH
	Patents ADP number *(if you know it)*	10777002

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
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		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	Yes

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Description 29

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Request for preliminary examination and search *(Patents Form 9/77)*

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11. I/We request the grant of a patent on the basis of this application.

Signature

Date 18 December 2002

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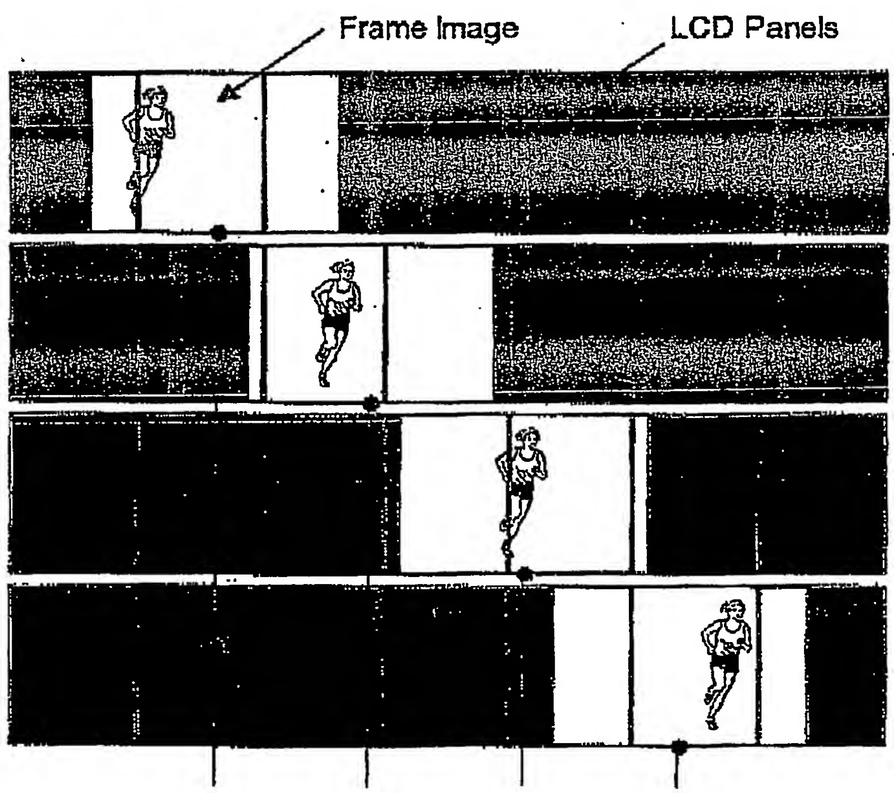
In Tunnel Advertising System: Interlacing Image Display with Digital Display Panels

Authors: Richard White, Jeff Evemy

Overview

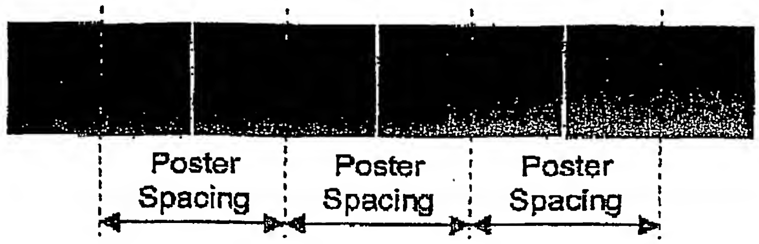
This document describes the In Tunnel Advertising System development to increase the display frame rate by interlacing images across large digital display panels. The display panels include LCD, TFT and other technologies. Each individual frame from a film sequence is stretched across multiple digital display panels that are back lit with Xenon strobe lamps that flash simultaneously to display the whole image there by making the panel size unimportant. The sequence then moves along flashing at the train windows to create the animation. Since the image position relative to the panels varies the panel borders are not noticeable in a frame sequence.



By generating a frame sequence where images span the

History

On poster-based systems, the frame rate of a system is determined as a function of the width of the image size and the velocity of the passing train.



Frame Rate = Posters per Second

Frame Rate = Train Velocity / Poster Spacing

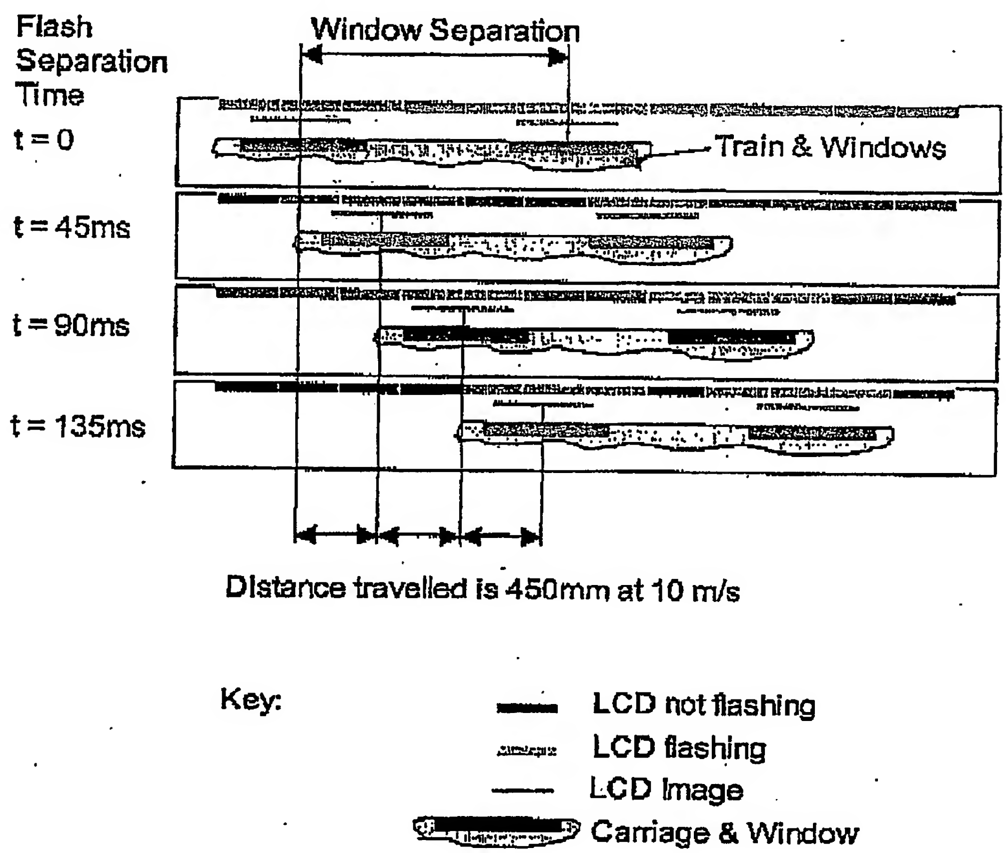
Using typical poster sizes of A2 or A3 with widths of 667mm and 573mm, the minimum train speeds for safe operation (at 22 frames per second) are 46kph and 53kph. This presents a limitation for use of the system to track sections where the train speeds are always over this and will result in loss of display if trains fall below this requirement.

Method

Using digital display panels to display the media, it is possible to display images that straddle two or more panels. By doing so the limitation of the relationship between image size and frame rate is removed. As the train passes the display, images are displayed by simultaneously flashing multiple panels across which the complete picture is stretched.

Without the technical restrictions of limited frame rates, the image size is deturmined by the train window size and distance from the tunnel wall. This results in typical image sizes of about 1 metre high by 1.8 metres wide. Using fixed posters this would require a minimum train speed of over 140 kph, however using digital display panels with this interlacing technique each digital display panel stores several images and loads them as required.

To maintain 22 frames per second equates to a flash separation of 45ms.



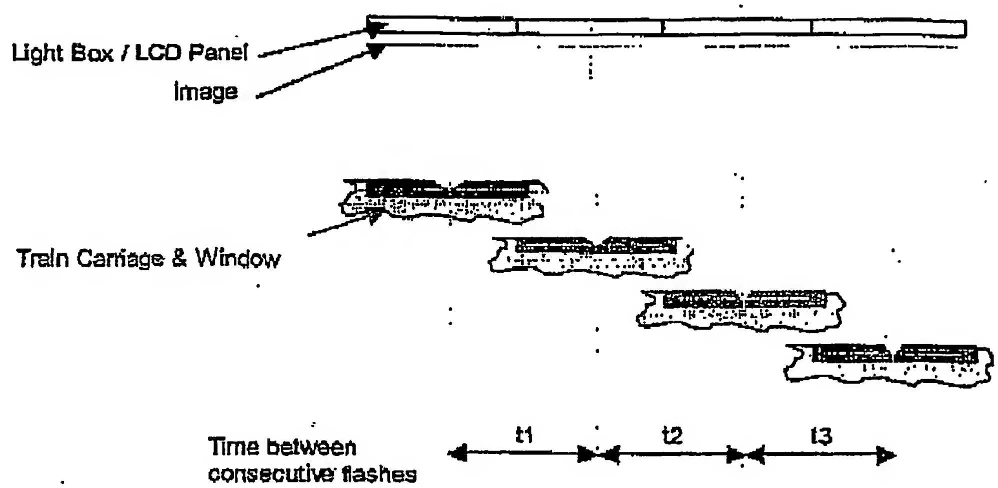
At a train speed of 10 m/s (36kph) the flash separation would need to be about 450mm. Since the image size is about 1.8 metres wide the digital display panels must flash 3 or 4 times as the train window / image passes.

Train Speed		Separation
m/s	kph	mm
1	3.6	45.45
2	7.2	90.91
3	10.8	136.36
4	14.4	181.82
5	18	227.27
6	21.6	272.73
7	25.2	318.18

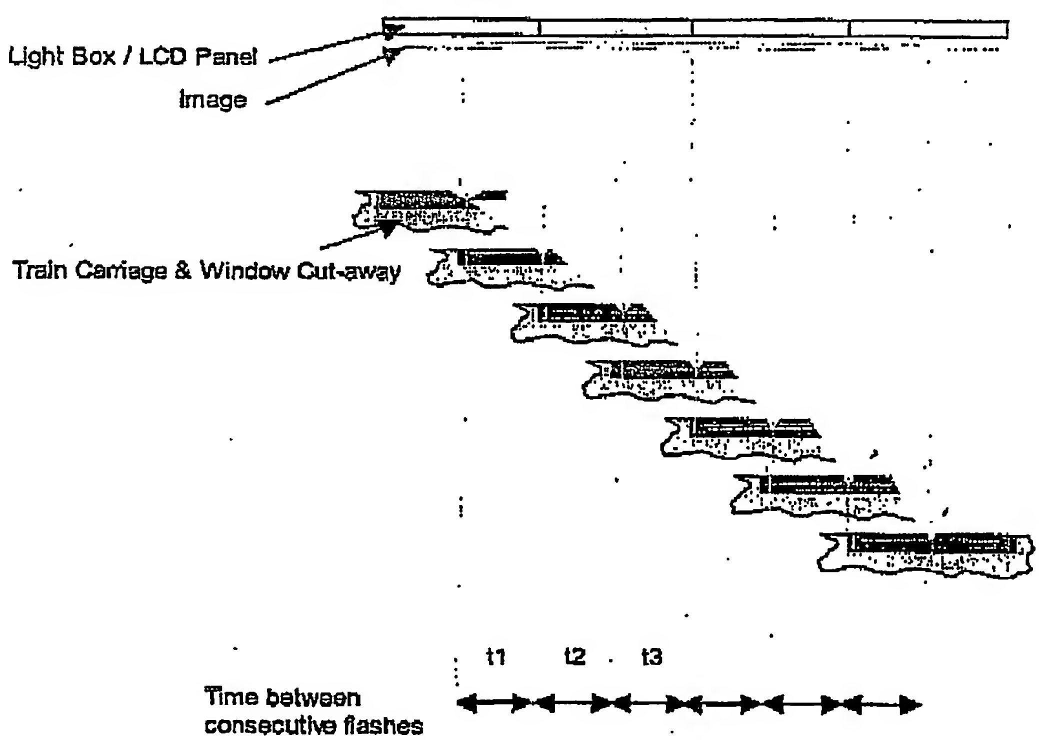
Train Speed		Separation
m/s	kph	mm
8	28.8	363.64
9	32.4	409.09
10	36	454.55
15	54	681.82
20	72	909.09
30	108	1363.64
40	144	1818.18

Creating an animation for slow track sections, a higher frame rate sequence can be generated and displayed over a shorter distance.

In addition to being able to operate in slow tunnel sections all locations benefit from a smoother image sequence with less flicker.



Standard Image Display without interlacing the image display



LCD Panel Image Display with interlacing the image display

Notes for New patent Application

Detector Algorithm

Problem

Assuming a number of cross track sensors, positioned to detect some feature on the train by the breaking or making of a beam.

In general:

- The sensors may be optical or infra-red.
- The sensors may use a unidirectional or bi-directional (retroreflective) beam.
- The sensors could use laser beams.
- The sensors would be arranged to maximise the clarity of measurement of the feature on the train e.g. the gap between the carriages.

The objective is to process the signals from these sensors in adjacent pairs so as to generate the timing for the same feature passing each sensor. The problem is that as the accuracy required is in the order of 1mm the measurements are frustrated by the presence of interfering objects such as pipes or cables which may be unexpectedly attached to the train.

In diagrammatic signal form, Figure 1 below presents the ideal situation:

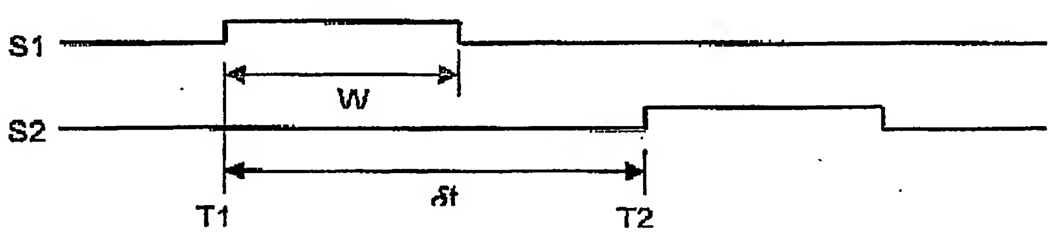


Figure 1. Ideal signals from sensors

Where S1, and S2 represent the signals from each of an adjacent pair of sensors with respect to time (the ordinate). The trace S1 shows the change in signal level as, for example the feature on the train passes causing the status of the beam to change for a period W, starting at time T1. An identical signal appears on trace S2 but at a later time, as the sensor is further along the track. In this straightforward case the timings are given by T1 and T2 respectively.

In the more general case, however, the effect of interfering objects is apparent as illustrated in Figure 2 below:

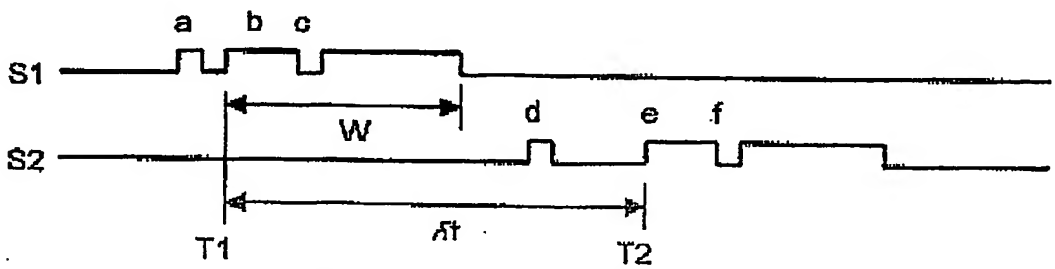


Figure 2. Typical signals from sensors

In this case the correct timings are again marked T1 and T2 but due to the effects of interfering objects there are other transitions of signals S1 and S2. These make the correct transitions less clear and the objective is to provide an algorithm to successfully extract them.

Solution

The solution of this problem requires a decision tree to be traversed as the sensor signals are generated. An example is given overleaf in Figure 4:

It can be seen that this algorithm has two paths, depending on whether S1 is initially on or off. This has the advantage that features causing occlusion of the beam work equally with features which clear the beam. For example, for a train in which the features are the gaps between carriages (see Figure 3 below) then detection occurs at the start of the train (beam occluded), and at the end of each carriage (clearing of beam) at the points marked 'C'. The start of subsequent carriages is ignored as it occurs during the processing of the previous feature (the distance between sensors is less than the length of the carriage). By this means, a train of n carriages, will enable n + 1 features to be detected at similar intervals.

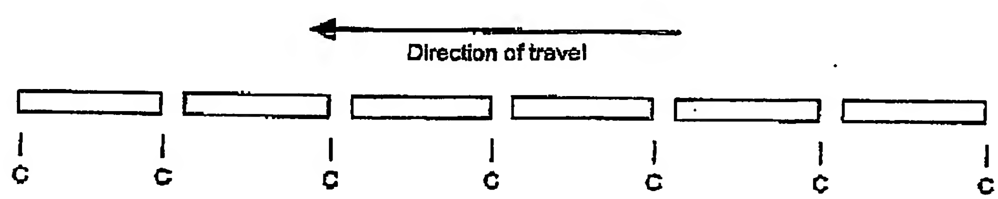


Figure 3. Illustration of timing points for six carriage train

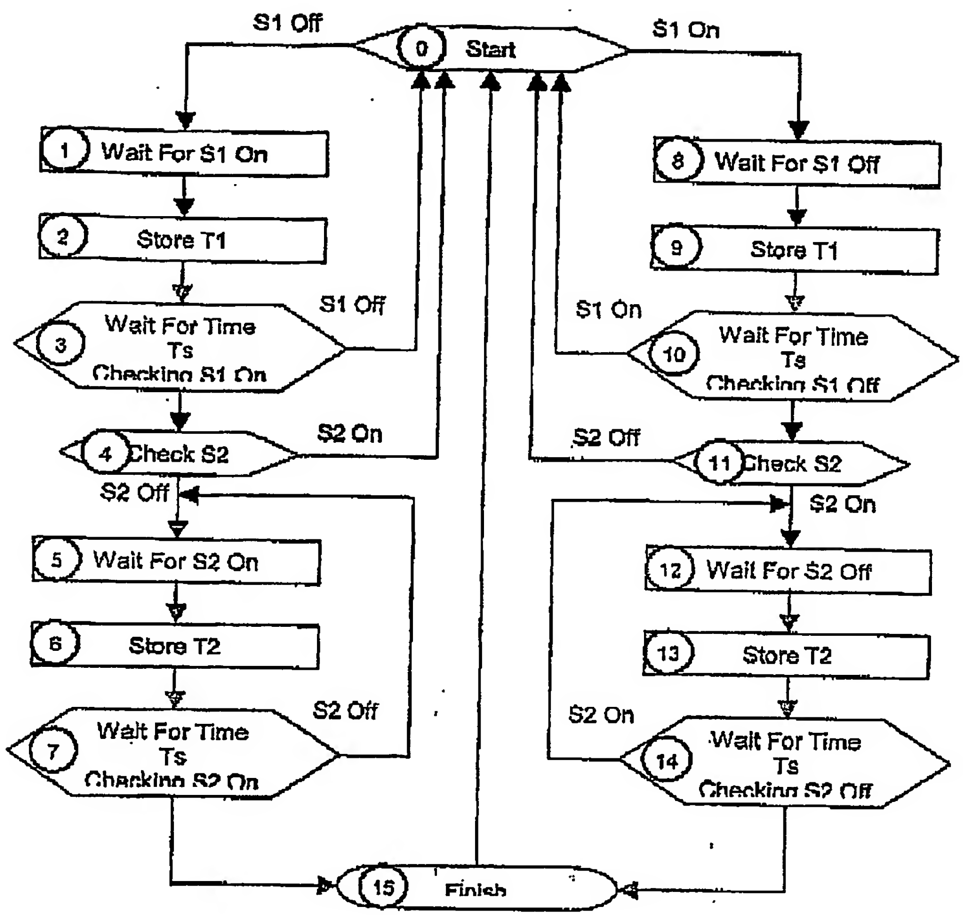


Figure 4 Example Sensor Processing Algorithm

With reference to Figure 2 the algorithm shown in Figure 4 works as follows:

As S1 is off at the start the algorithm initialises in State 1, waiting for S1 to turn on. At point 'a' the algorithm proceeds through State 2 (storing an initial value for T1) to State 3 and waits for time Ts whilst checking S1 is still on. Ts, however, is predetermined to have a value greater than the width of the pulse at 'a' and as S1 becomes off before Ts has elapsed, the algorithm returns to State 0 and restarts.

At point 'b', the algorithm proceeds again from State 1 through State 2 (storing an updated value for T1) to State 3 and as the length of pulse 'b' is longer than Ts the algorithm then proceeds to State 4 and thence to State 5, now ignoring signal S1 and monitoring signal S2.

At point 'd' the algorithm proceeds through State 6 (storing an initial value for T2) to State 7 and waits for time Ts whilst checking S2 is still on. Ts, however, is predetermined to have a value greater than the width of the pulse at 'd' and

as S2 becomes off before Ts has elapsed, the algorithm returns to State 5 and waits for S2 to become on again.

At point 'e', the algorithm proceeds again from State 5 through State 6 (storing an updated value for T2) to State 7 and as the length of pulse 'e' is longer than Ts the algorithm then proceeds to State 15 and generates a flag to indicate that the values for T1 and T2 are valid.

The algorithm then restarts and looks for the next change in S1. It can be seen that:

- The values T1 and T2 are correct, provided that an appropriate value for Ts is chosen. This should be sufficient to ignore interfering objects but not preclude the genuine size of the required feature.
- The algorithm, under the conditions shown in Figure 3 (assuming S1 to be on when no train is in the tunnel) will first take the route through States 8 to 14 (detecting the front of the train), and thereafter take the route through States 1 to 7 (detecting the back of subsequent carriages) and finish at the back of the train. Providing the timing points as shown in Figure 3.

Improvements

The algorithm may be improved by any combination of the following:

- A timeout period may be added to States 7 and 14 so that if an error has caused the misrepresentation of T1 then the algorithm will ignore this and restart.
- Clearly the effects of interfering objects is asymmetric; this can be reflected in the algorithm. For example, pulse 'd' is unlikely to happen in reality (unless there is a hole in the carriage) and moreover pulse 'e' may be short if there is an interfering object close to the back of the carriage. In this case State 7 should be removed. A similar argument could be applied to the removal of State 10.
- The values of Ts could be different for States 3, 7, 10 and 14.
- Additional states could be added to ensure that the detection of S1 and S2 falls within a window after previous detection events to abrogate the effects of serious interfering objects (such as a pantograph halfway along a carriage roof).

In Tunnel Advertising System Calibration Process Using Statistical Profiling and High Frequency Drift Containment

Authors: ***Matthew Davis, Vicki Parsons, Jeff Evemy, Jo Caudrey, Vince Johnson, Richard White***

Overview

This document describes the In Tunnel Advertising System calibration process. Building Statistical Profiles of the trains passing any given system overcomes the real world variations in train geometry.

The variations are caused by a number of factors: build variation, ride height, wear and tear and non-standard additions to the exterior of the train. There are further errors introduced through system installation resulting in differences between the measured and actual sensor locations and heights; these will also affect the times recorded for sensor cuts, and hence the velocities generated.

The differences in geometry from train to train, and against the engineering design drawings, cause the image position in each window to deviate from the expected steady mid-position. By analysing the data from many train runs passing the system, it is possible to build a profile of train runs then calculate a set of calibration values that best fit the 'typical' profile. Different types of profile can be recognised in real time as the train passes the system and through this calibration process these real-world variations are eliminated.

Since the human eye is very sensitive to sudden movement, it has been realised that to produce the best perceived display a careful balance has to be struck, minimising the overall image drift while containing high frequency drift oscillations to within acceptable limits.

System Anatomy:

The system measures position, velocity and accelerations from passing trains using sets of cross-track light-beam sensors. When the front of the train, or back of each carriage, passes a sensor beam the position of the train at that instant is known. Velocities are calculated from the time taken for the train to travel from one sensor to the next. These pairs of sensors are described as *detectors*. Similarly accelerations are calculated from sequential detector velocities.

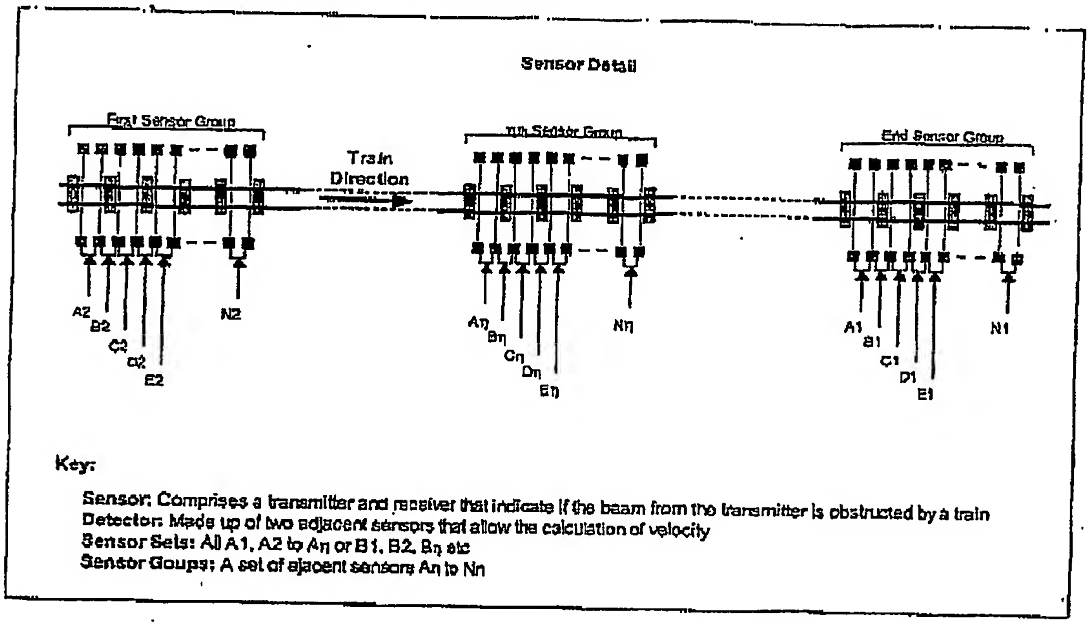


Figure 1

Measured dimensions of a system that are used in the calculation of position, velocity and acceleration are Sensor-Spacing, System-Offset and Sensor Group Gap. The accuracy of these measured dimensions critically affect the operation of the system and form part of the fundamental elements that must be calibrated to eliminate inaccuracies in the building of a system.

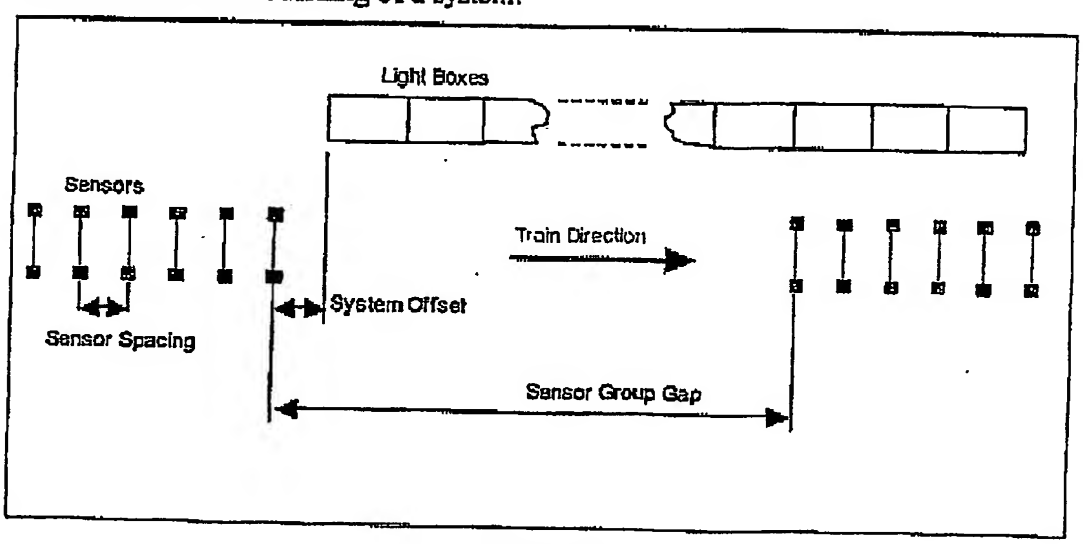


Figure 2

As the train progresses through a sensor group each event (i.e. the front of the train or back of a carriage passing a sensor) is known as a sensor cut point. Sensor cut points generated from the second sensor in a group onwards, are known as *detector cut points*.

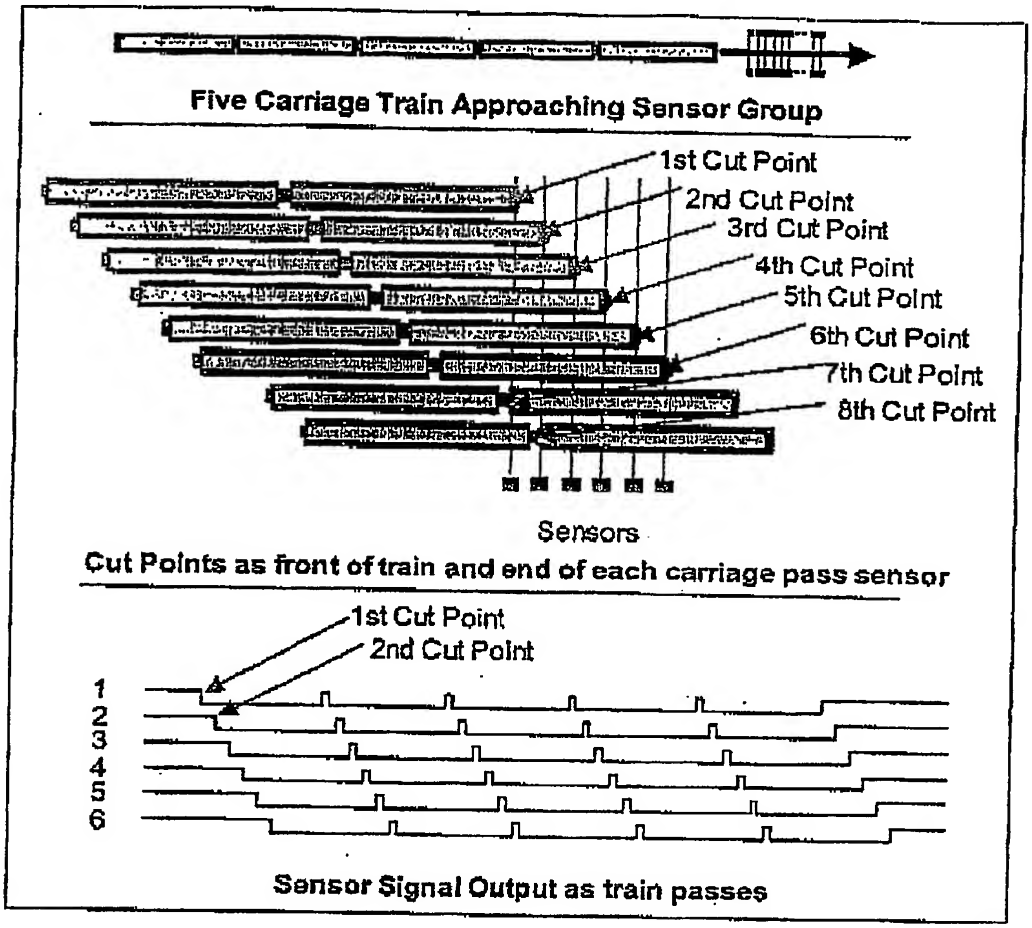


Figure 3

Calibration Process

The calibration process is performed in two stages:

- velocity calibration
- positional calibration.

Velocity calibration.

Velocity data from many trains is collected. Using this data, the system's sensor (spacing and height) build variations are eliminated.

Line of best fit

The 'line of best fit' is applied to each set of train data using an appropriate model. This may be least squares regression, polynomial or other method. An example of this is a cubic approximation.

Having determined the line of best fit the error for each data point (ie the distance from the data points to cubic line) is calculated.

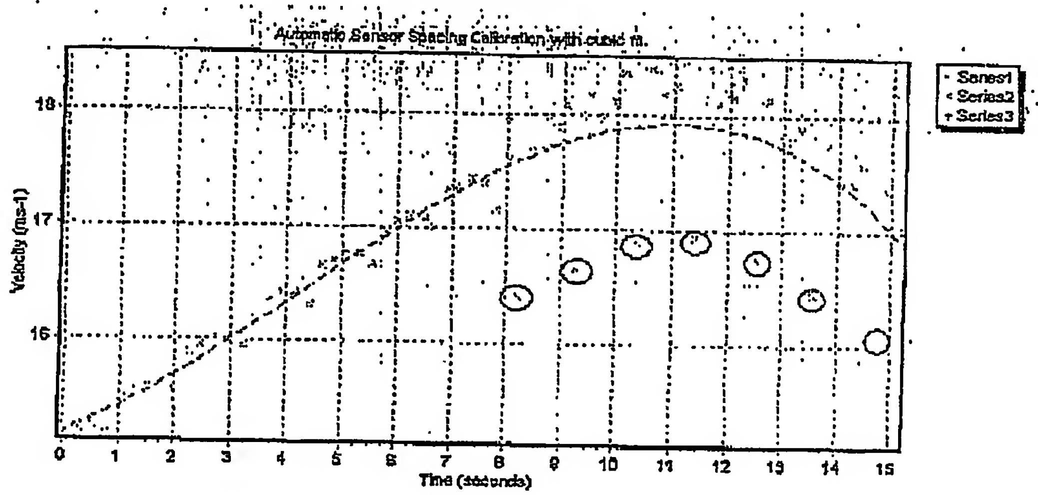


Figure 4: Measured velocities for an un-calibrated system.

Calibrating the Sensor Spacing

The graph of measured velocities for an un-calibrated system, shows an extreme example of a sensor spacing error (circled in blue). The circled points belong to a detector whose measured sensor spacing is smaller than it's actual spacing. This produces low velocity readings.

To correct the sensor spacing error, the data point errors are treated as a sensor set where a single best fit coefficient is calculated and applied to the whole set.

Calculation of correction coefficient

```
Coefficient = mean (1 + ((model value - measured velocity) / model value))
```

Where the mean is the error across a detector set.

Average across many trains

The Velocity Calibration is repeated for many trains to create an average correction coefficient for each detector. The new spacing values are moved to the line of best fit by

```
New spacing = Old spacing / (mean (Coefficient))
```

This is the mean correction coefficient across many trains.

Individual Cut-Point Calibration

Having corrected the Sensor Spacing Errors to produce a smooth, well-fitted data set, individual points will still be consistently low or high and off our best fit curve. By analysing many trains these points can be individually calibrated onto the line of best fit. The ringed readings at the start and in the middle of the graph are where the front of the train enters the first and second group of sensors.

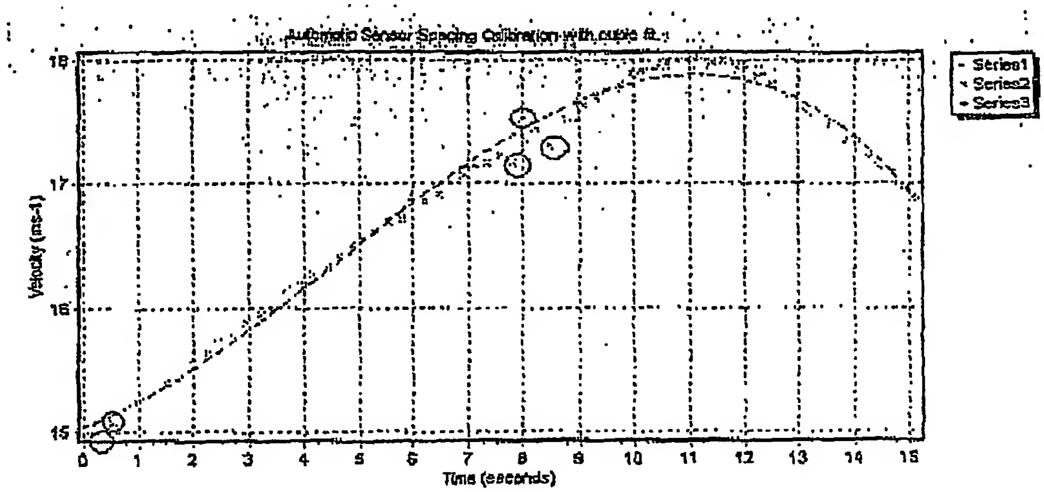
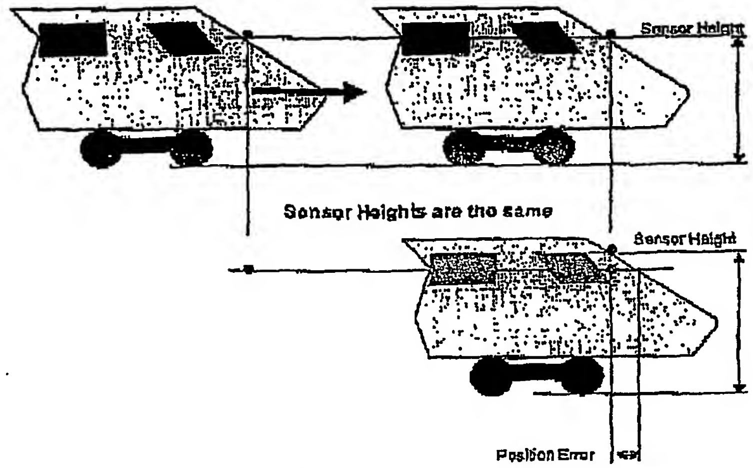


Figure 5

These individual cut errors are caused by inaccurate sensor height placing and are likely to affect the cut points for front and rear of trains with a sloping cab.



Sensor Height Higher than previous sensor

Figure 6

Variation in sensor height gives a false sensor spacing because the front of the train is sloping.

To correct these errors we need to log many trains and look for individual sensor cuts that are consistently in error.

Coefficients are applied to each sensor cut to bring all values towards the optimal 'line of best fit'.

The analysis of the train data is performed by computer with the coefficients programmed into the control system and the first stage of the calibration is complete.

Image Position Calibration

In this section of calibration the position of the image relative to the train window is calculated and controlled to improve the image quality.

The control system produces the predicted time at which each sensor cut should occur. These are compared with the actual sensor cut times, which effectively gives a positional error. It is possible to reduce the positional error by adjusting the sensor group positions relative to the system.

Sensor stretch

Sensor stretch is the co-efficient used for correction of sensor group positions. This will reduce oscilations in the image.

In the first part of the calibration procedure sensor positions are individually corrected. The sensor sets are at measured positions in the tunnel, which are relative to the system. As each carriage cut point passes a sensor group the position of the image will vary in the window. There is a cumulative error in position that is not seen in the previous individual velocity calculations. This produces a difference in the predicted image position and the recorded train position. To align the image in the centre of the window, there is a need to adjust sensor group positions, relative to the system.

For a given train run the system records the difference in position of image to train.

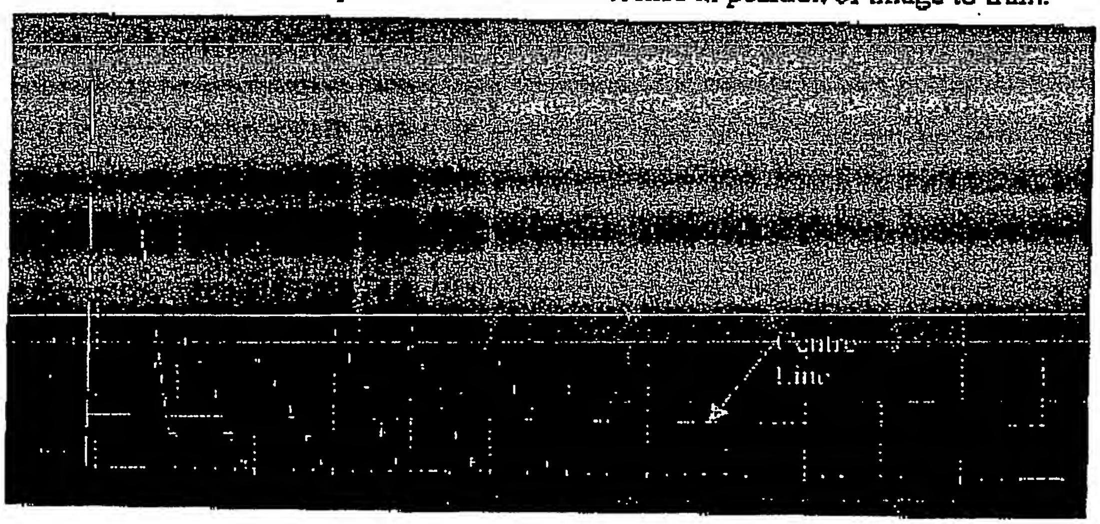


Figure 7

Figure 7 shows drift error recorded for a sample train. The zero line is the point where the image is central in the window. Points above this line will indicate that the image is ahead of the centre of the window, points below the line are behind. The red fitted lines are approximating the gradient of drift readings for each sensor set.

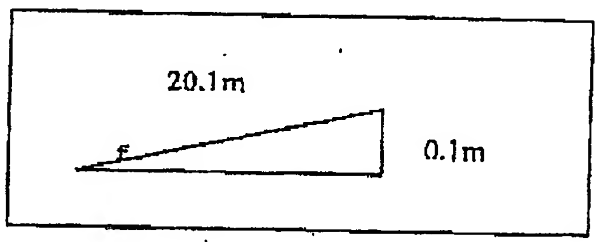
For the example shown in Figure 7 there is a general movement of the image from ahead of the central position to behind. This movement is across each sensor group. As each feature on the train starts to cross the sensor group, the image returns to the initial position, ahead of the central point. This lateral movement makes the image

difficult to follow. To improve the image quality the difference in position of image to train should be kept as constant as possible (i.e. The drift should be kept to a minimum).

In the example shown on figure 7, the picture drifts backwards. It is therefore necessary to artificially increase the distance of the sensors from a *pivot sensor* in the group. In the first group the pivot sensor is the last sensor position. This is so that when adjustments are made to the sensor positions, the offset from the first group to the start of the system is constant. In all subsequent groups the first sensor is the pivot.

By keeping the pivot sensor fixed and moving other sensors in the group by a correctional factor, all drift points will be in error equal to the pivot point. In figure 7 the drift for the first sensor group will approach –0.05m.This stretch to the sensor sets has the effect of flattening the lines on this graph (see figure 9). The average gradient, for each sensor set, is taken over all train runs. A different sensor stretch coefficient is taken for each sensor group.

Example 1: gradient calculation.



In an ideal situation the drift should be zero. In this example the image drifts 10cm over 20.1m of train distance covered. The distance is in error by 10cm and should really measure 20m. In order to bring the drift line down to the horizontal, and therefore the drift to zero, the gradient is taken

$$f = \tan^{-1}(0.1/20.1) = 0.00498$$

The mean gradient for all sensor sets over many runs is calculated. This can be converted to a stretch by using the equation:

$$\text{Stretch} = 1 - \tan(\text{average gradient})$$

This gives a stretch of 0.9950. This can be verified by multiplying the original distance by our stretch factor, giving our corrected distance of 20m (20.1 * 0.9950 = 20m). This works equally for negative gradients, this gives sensor stretches greater than 1.

End of Example

After the stretch factors are applied the following graph is produced

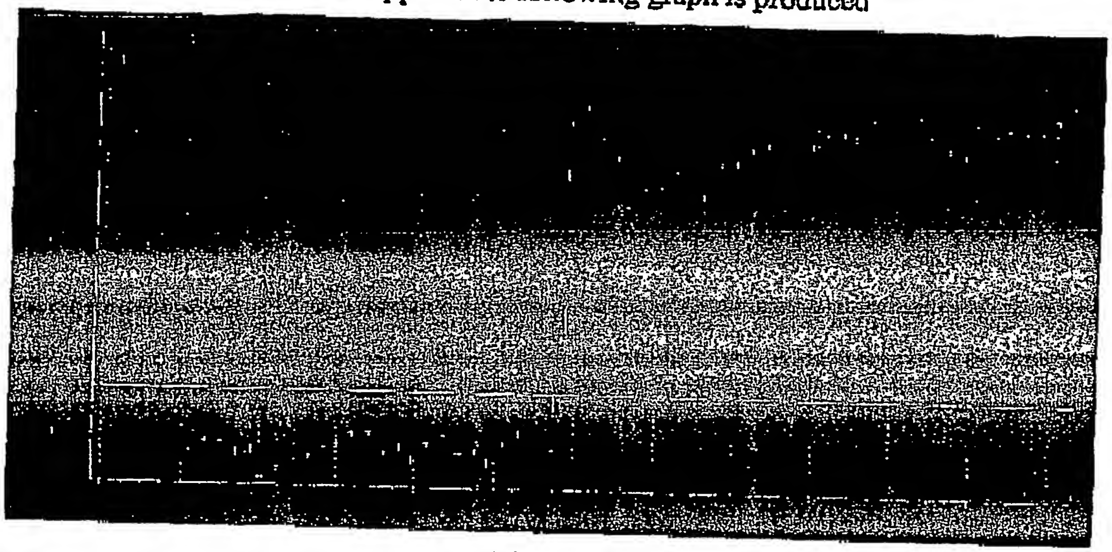


Figure 9

Sensor group offset

Following the sensor stretches the drift remains stable. However, as can be seen from the graph above, the image position may not be the centre of the window. This can be corrected by shifting the sensor groups by a fixed offset amount.

On the above example during the first sensor group the picture is approximately 0.05m behind the centre point. To correct this the group is given an offset of –0.05m. This will move the *trigger point* relative the light boxes and so the picture will start showing sooner. The second group is moved relative to the first group, and so the between sensor group gap is increased. It is likely that there will have been a measurement error here, as we need to be accurate to millimetres over approximately a 100m gap.

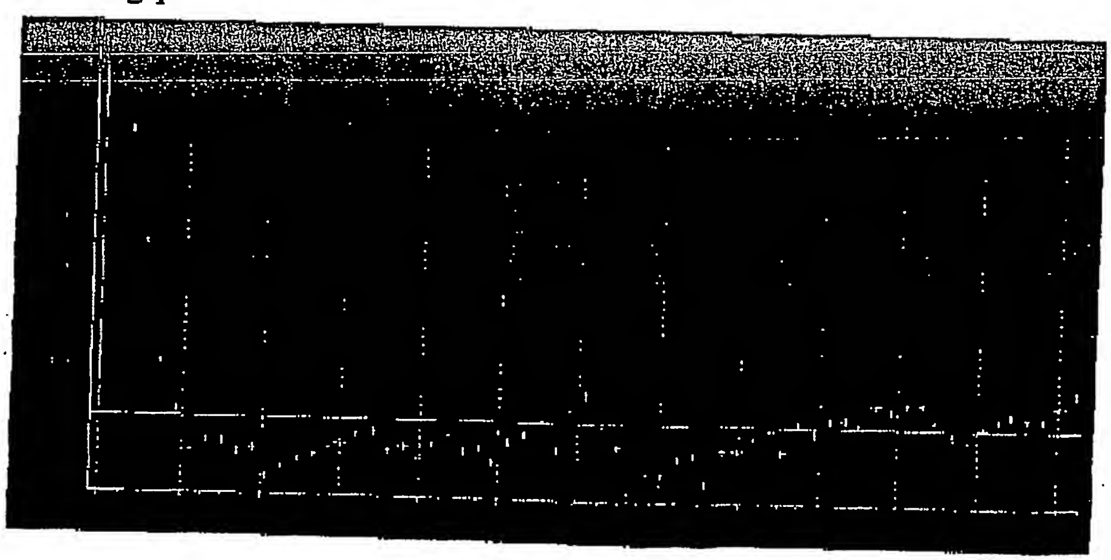


Figure 10

Figure 10 shows the drift after the sensor group offsets have been applied. The image now centres around the zero line at the centre of the train window. The positional error is initially high but is 5cm or less for the majority of the run.

Filtering and Parameter control

The train runs should now have very little positional error. They can be further fine tuned by adjusting the parameters used in the application in the control boxes used during an actual run.

The amount of error corrected as each new train position comes in is dependant on several parameters which are sent to the system. These tell the system the proportions in which to use current data vs predicted data, new data vs previous measurements, the point at which to apply any corrections and large error correction terms.

There are a number of methods we combine to find the parameters that optimise performance in a given system.

a. The first is iteratively, by running the same trains through a simulation system and finding values that give the best results. Simulation allows identical train runs to be logged with different parameter sets. The set that produces the least drift can then be transferred to the system.

b. Transforming positional error data from the time domain into the frequency domain by using a Fourier transform, and selecting parameter values which reduce the high frequency components to a minimum. Reduction of high frequency noise ensures corrections will be applied gradually producing a smooth picture after calibration.

c. By using initial seed values, which have already been determined through manual calibration.

Using the filters, Fourier transforms and other methods described above it is possible to reduce errors such as at the start of the example system. By altering parameters used in the real time algorithm train runs with rapidly altering accelerations and other behavioural characteristics, will have reduced drift on subsequent runs as control parameters optimise performance for the profile of a given system.

Notes for New patent Application

Difference Engine

Problem

Assuming updated values for velocity and acceleration there is a need to generate timing pulses to fire the Xe lamps in the display boxes in real-time.

Issues:

- After initialisation at a fixed position, velocity and acceleration may be changed, but the position may not as any discontinuities will be visible and highly distracting.
- High timing accuracy is required; the display pulses should be accurate to within 50μs or less (corresponding to 1mm at 20ms^{-1}).
- In order to generate the display pulses, it is necessary to know the position of the train at all times.
- High positional accuracy is required, subsequent frames of each image must be positioned to within 1mm or less to avoid jitter.
- Timing pulses need to be generated for all the display boxes and for all the windows in which the display is to be presented.
- The position needs to be available as an instantaneous value in order that external processes (for example co-incidence with a sensor beam) may use this information to update acceleration and velocity estimates.

The objective is to generate the display timing pulses in real-time from a known starting position, assuming updated velocities and acceleration and with prior knowledge of the position of the display boxes and the position of the windows on the train.

Solution

The solution of this problem requires two factors:

1. The solution of the equation of motion:

$$s = \iint a \cdot dt^2 + \int v \cdot dt + k \qquad (1)$$

for position s at a given time t, where a and v are instantaneous values of acceleration (d^2s/dt^2) and velocity (ds/dt) respectively and k is the initial position or offset.

2. The generation of display pulses using this position information and the known position of both windows and display boxes.

<u>Equation Of Motion</u>

Assuming the integration can be performed numerically the number of calculations can be reduced by rearranging (1) to give:

$$s = + \int (v + \int a \cdot dt) \cdot dt + k \qquad (2)$$

The integrations are definite (from 0 to t) and in numerical terms with discrete time units δT may be represented:

$$s = \sum_{T=0}^{t} (v + \sum_{T=0}^{t} a \cdot \delta T) \cdot \delta T + k \qquad (3)$$

As δT remains constant v and a may be appropriately scaled thus:

$$V = v \cdot \delta T \qquad (4)$$

and:

$$A = a \cdot \delta T \qquad (5)$$

Assuming that the summation is performed in steps of δT therefore, (3) may be simplified to:

$$s = \sum^{t} (V + \sum^{t} A) + k \qquad (6)$$

This calculation may be implemented using the architecture shown below:

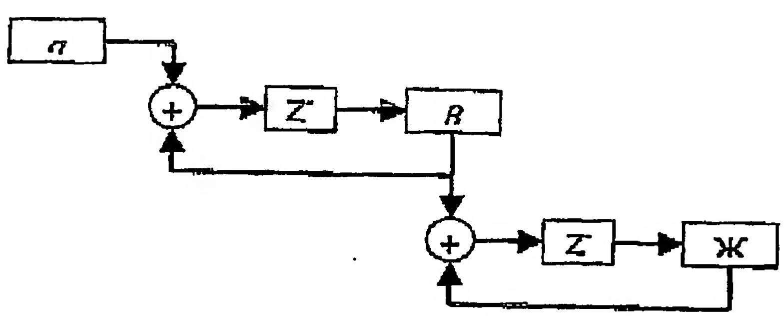


Figure 1. Implementation of Equation of Motion

The operation can be described as follows:

Blocks α, β, and Ж are registers which may be loaded and read by the control system (e.g. a microprocessor) and may be of arbitrary resolution.

Blocks marked Z^{-1} represent registers of appropriate resolution which implement a delay of δT.

Initially registers α, β and Ж are loaded with the initial values of A, V and k appropriately scaled as described above.

Thereafter registers α and β are loaded with the updated values of A and V as they are calculated from measurement values by other processes in the system.

Register Ж gives the instantaneous value of position.

This implementation has the following advantages:

- Acceleration values may be updated at any time.
- Velocity values may be updated at any time.
- Value of δT is limited only by the speed of the adders and may therefore be very small.
- Resolution of acceleration, velocity and intermediate results may be arbitrarily defined and is independent of δT.
- Velocity and position values are available to external processes at any time.

<u>Generation of Display Pulses</u>

This information can be used to generate the display pulses by continually comparing the current position (given by register Ж) with that which represents the coincidence of a particular window with a given display box.

This may be achieved using the algorithm shown in Figure 2 overleaf.

The nomenclature is as follows:

- W represents a particular window on the train.
- B represents a particular display box on the tunnel wall.
- $\omega(B)$ represents the next window to pass display box B.
- P_B represents the position of display box B.
- $P_{\omega(B)}$ represents the position of the next window to pass display box B.
- Ж represents the instantaneous value of position as calculated above.

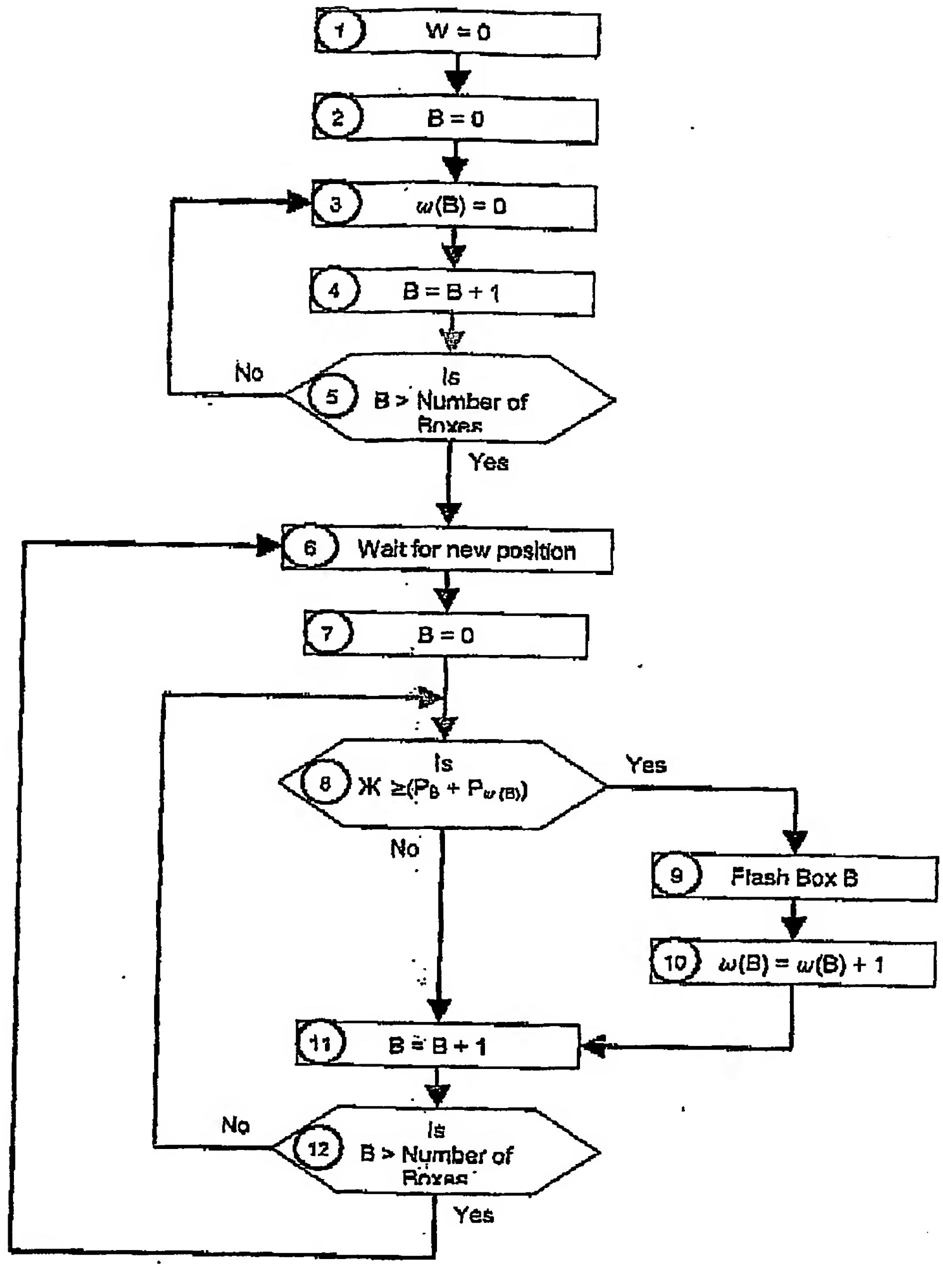


Figure 2. Generation of Display Pulses

The algorithm operates as follows:

It is assumed that the algorithm is initialized to State 1 before a train passes the system. Thence W and B are initialized to zero and through States 3, 4, and 5 the values of $\omega(B)$ are initialized to zero for all the display boxes.

The algorithm waits in State 6 until a new position is calculated; it is assumed that this only happens after a train is detected. Then in State 7 the box count is reset to zero and States 8 through 12 are repeated for each box before returning to State 6 to wait for the train to move to the next position.

During State 8 it is determined if the train has moved such that the position of the next window coincides with the current display box. If so, a flash is generated for that display box and $\omega(B)$ is set to point to the next window.

The algorithm ends when the last window passes the last box or a time out elapses (neither shown in the flowchart), after which the algorithm proceeds to State 1 and waits for the next train.

An important aspect of this algorithm is that it is bounded by the number of boxes per control system and is independent of the number of windows. It is only necessary that both the boxes and windows are in the correct sequence.

More importantly, because the number of states is bounded, the algorithm may be implemented by a state machine, which operates in finite time; and can therefore be implemented to coincide with each step of the position generator described previously. Thereby providing the necessary degree of accuracy.

Improvements

The system as described may be improved by any combination of the following:

- In addition to instantaneous access, the difference engine (with suitable synchronising registers) may be configured to allow simultaneous update of any combination of position, velocity and acceleration. This allows any algorithm used to process measurements and calculate acceleration and velocity to:
    - Compare positions of events with actual ones; using the error to dynamically control the equation of motion (1).
    - Monitor performance and apply meaningful physical limits to acceleration and any discontinuities in velocity or position.
    - Avoid discontinuities altogether by modifying acceleration only; using feedback from both velocity and position errors.
- The design shown in Figure 1 has a clear structure whereby the acceleration processing is a cascaded element to the velocity processing. This may be extended by cascading additional elements, effectively adding third, or higher order integrations to the equation of motion (1). This may be useful for the following reasons:
    - The physical causes (e.g. rate of change of acceleration due to application of brakes etc.) may be known and added to the model used to process the measurements.
    - Higher order terms may allow better dynamic control.
    - Higher order terms may assist stability of the overall system.

- The algorithm illustrated in Figure 2 uses values of P_B that clearly represent the position of the display boxes on the tunnel wall. Variation of these gives the following advantages:
  - Allowances may be made for irregular spacing of the display boxes, such as to avoid an obstruction on the tunnel wall.
  - The values may be changed to represent the virtual position of the box relative to the train. This is important, for example, when part of the display is situated on a curved section of tunnel. In this case equally spaced boxes will appear in different positions, relative to their projection onto a curve of larger or smaller radius. This error can be abrogated by using values of P_B that compensate for the difference between arc lengths.
  - By applying a mapping function to the set of values the virtual position of any particular display box may be moved. As each display corresponds to an individual frame (which is fixed in time in the sequence as perceived by the viewer); this provides a simple method whereby the position of the display relative to the window may be made to follow a predetermined function of time.

For example, if we consider the simple case in which we wish to move portions of the display (as presented to the viewer) then the mapping function $f(t)$ is simply the difference between the real and virtual positions and is defined by the following:

$$f(t) = p(t) - P \qquad (7)$$

where t is the time into the movie, P is the normal position of the display with respect to the window, p(t) is the required position as a function of t.

Then, by applying the function to values of P_B to generate new values P_B' gives:

$$P_B' = f(T_B) + P_B \qquad (8)$$

where T_B is the time associated with the frame represented by display box B, given by:

$$T_B = B / F \qquad (9)$$

Where F is the frame rate.

Combining (8) & (9);

$$P_B' = f(B / F) + P_B \qquad (10)$$

Hence by simply selecting an appropriate mapping function $f(t)$, and using the "virtual" values P_B' in the equation of State 8 we can implement any manipulation of the image which may be derived or desired.

Notes for New patent Application

Detector Algorithm

Problem

Assuming a number of cross track sensors, positioned to detect some feature on the train by the breaking or making of a beam.

In general:

- The sensors may be optical or infra-red.
- The sensors may use a unidirectional or bi-directional (retroreflective) beam.
- The sensors could use laser beams.
- The sensors would be arranged to maximise the clarity of measurement of the feature on the train e.g. the gap between the carriages.

The objective is to process the signals from these sensors in adjacent pairs so as to generate the timing for the same feature passing each sensor. The problem is that as the accuracy required is in the order of 1mm the measurements are frustrated by the presence of interfering objects such as pipes or cables which may be unexpectedly attached to the train.

In diagrammatic signal form, Figure 1 below presents the ideal situation:

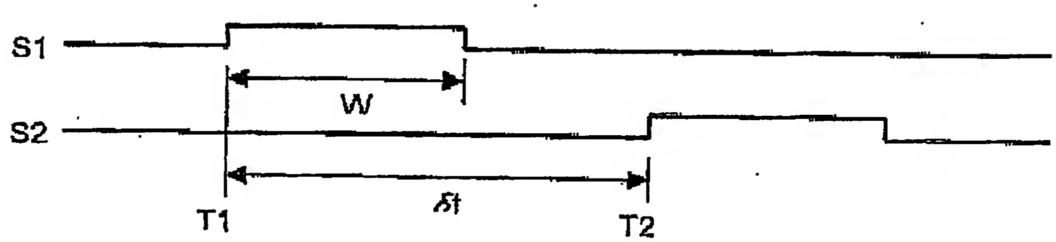


Figure 1. Ideal signals from sensors

Where S1, and S2 represent the signals from each of an adjacent pair of sensors with respect to time (the ordinate). The trace S1 shows the change in signal level as, for example the feature on the train passes causing the status of the beam to change for a period W, starting at time T1. An identical signal appears on trace S2 but at a later time, as the sensor is further along the track. In this straightforward case the timings are given by T1 and T2 respectively.

In the more general case, however, the effect of interfering objects is apparent as illustrated in Figure 2 below:

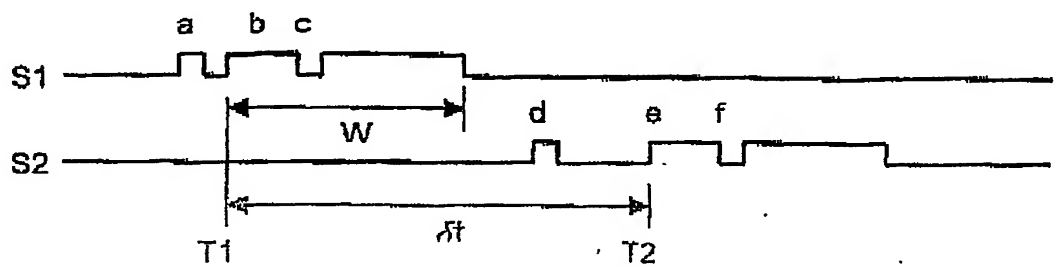


Figure 2. Typical signals from sensors

In this case the correct timings are again marked T1 and T2 but due to the effects of interfering objects there are other transitions of signals S1 and S2. These make the correct transitions less clear and the objective is to provide an algorithm to successfully extract them.

Solution

The solution of this problem requires a decision tree to be traversed as the sensor signals are generated. An example is given overleaf in Figure 4:

It can be seen that this algorithm has two paths, depending on whether S1 is initially on or off. This has the advantage that features causing occlusion of the beam work equally with features which clear the beam. For example, for a train in which the features are the gaps between carriages (see Figure 3 below) then detection occurs at the start of the train (beam occluded), and at the end of each carriage (clearing of beam) at the points marked 'C'. The start of subsequent carriages is ignored as it occurs during the processing of the previous feature (the distance between sensors is less than the length of the carriage). By this means, a train of n carriages, will enable n + 1 features to be detected at similar intervals.

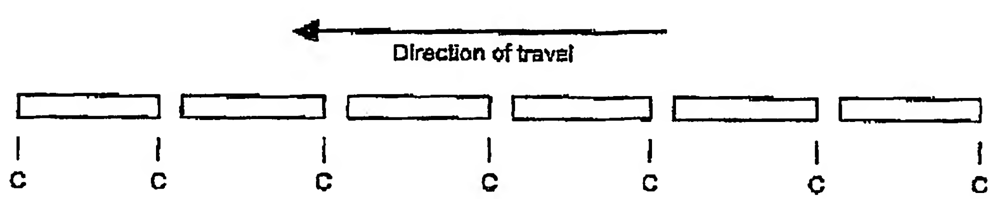


Figure 3. Illustration of timing points for six carriage train

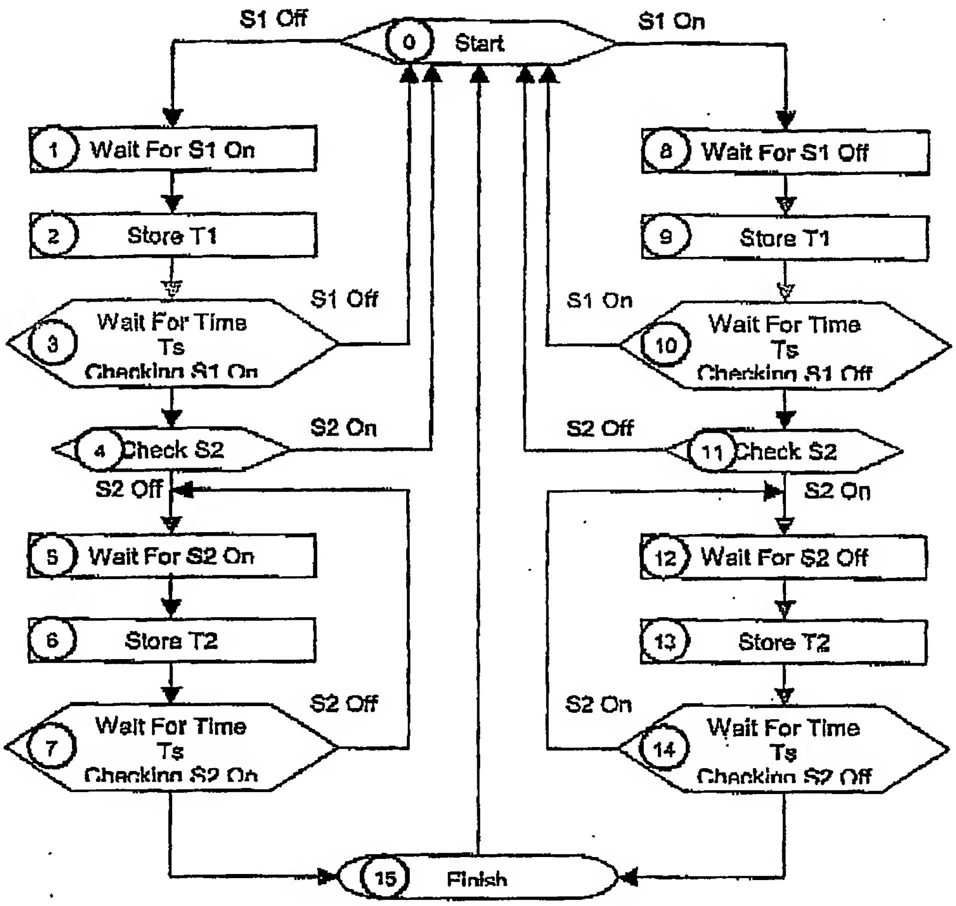


Figure 4 Example Sensor Processing Algorithm

With reference to Figure 2 the algorithm shown in Figure 4 works as follows:

As S1 is off at the start the algorithm initialises in State 1, waiting for S1 to turn on. At point 'a' the algorithm proceeds through State 2 (storing an initial value for T1) to State 3 and waits for time Ts whilst checking S1 is still on. Ts, however, is predetermined to have a value greater than the width of the pulse at 'a' and as S1 becomes off before Ts has elapsed, the algorithm returns to State 0 and restarts.

At point 'b', the algorithm proceeds again from State 1 through State 2 (storing an updated value for T1) to State 3 and as the length of pulse 'b' is longer than Ts the algorithm then proceeds to State 4 and thence to State 5, now ignoring signal S1 and monitoring signal S2.

At point 'd' the algorithm proceeds through State 6 (storing an initial value for T2) to State 7 and waits for time Ts whilst checking S2 is still on. Ts, however, is predetermined to have a value greater than the width of the pulse at 'd' and

as S2 becomes off before Ts has elapsed, the algorithm returns to State 5 and waits for S2 to become on again.

At point 'e', the algorithm proceeds again from State 5 through State 6 (storing an updated value for T2) to State 7 and as the length of pulse 'e' is longer than Ts the algorithm then proceeds to State 15 and generates a flag to indicate that the values for T1 and T2 are valid.

The algorithm then restarts and looks for the next change in S1. It can be seen that:

- The values T1 and T2 are correct, provided that an appropriate value for Ts is chosen. This should be sufficient to ignore interfering objects but not preclude the genuine size of the required feature.
- The algorithm, under the conditions shown in Figure 3 (assuming S1 to be on when no train is in the tunnel) will first take the route through States 8 to 14 (detecting the front of the train), and thereafter take the route through States 1 to 7 (detecting the back of subsequent carriages) and finish at the back of the train. Providing the timing points as shown in Figure 3.

Improvements

The algorithm may be improved by any combination of the following:

- A timeout period may be added to States 7 and 14 so that if an error has caused the misrepresentation of T1 then the algorithm will ignore this and restart.
- Clearly the effects of interfering objects is asymmetric; this can be reflected in the algorithm. For example, pulse 'd' is unlikely to happen in reality (unless there is a hole in the carriage) and moreover pulse 'e' may be short if there is an interfering object close to the back of the carriage. In this case State 7 should be removed. A similar argument could be applied to the removal of State 10.
- The values of Ts could be different for States 3, 7, 10 and 14.
- Additional states could be added to ensure that the detection of S1 and S2 falls within a window after previous detection events to abrogate the effects of serious interfering objects (such as a pantograph halfway along a carriage roof).